Wind Power

Uses and Potential

A Renewable Energy Source

TransAlta Utilities

93-01805/

Table of contents

2	An introduction to wind power
4	Types of rotors and wind machines
6	Calculating available wind energy
8	Possible sites
11	Possible uses
14	Interconnection of Small Wind Energy Conversion Systems
15	Interconnection policy of TransAlta Utilities
17	Costs
18	More information

A joint publication prepared by:

Alberta Agriculture
Engineering Services Branch
Room 201, 7000 - 113 Street
Edmonton, Alberta
T6H 5T6

TransAlta Utilities
Power Planning
Box 1900
Calgary, Alberta
T2P 2M1

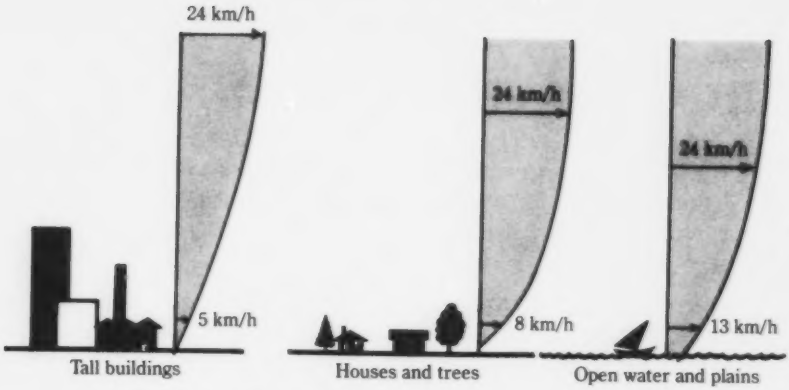
An introduction to wind power

Over 30 years ago, wind-generated power played an active part in the electrification of many rural homesteads in Alberta. This era ended with the organization of Rural Electrification Associations (REAs).

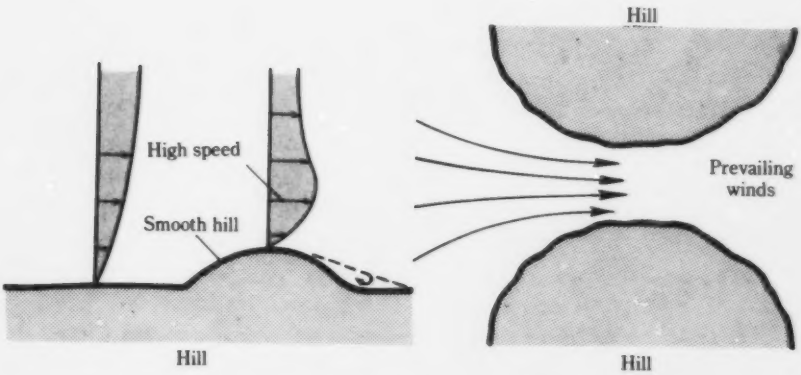
Today, wind machines are still used for pumping water and some have been reactivated or installed to produce power. Many people in rural areas are also considering wind energy for various farm applications.

The principal factors affecting the amount of power generated by a wind machine are the area swept by the rotor and wind speed. Usually a minimum average wind speed of 12 to 14 kilometres per hour is required to operate a wind machine. Doubling the area swept by the rotor will double power output, but doubling the wind speed will increase power output eightfold. Therefore, a wind machine should be positioned to take the best advantage of prevailing winds.

Wind speed is affected by topography (hills and valleys) and by surface obstructions (buildings and trees). Certain topographical features can augment wind speed. For example, winds increase when funneled into a valley and will also increase near ground level at the top of a smooth hill. Obstructions, on the other hand, tend to reduce wind speed near the ground. Since wind speed increases with elevation, to maximize power output from a wind machine, a cost comparison should be made between increasing the rotor area and increasing tower height.



Effect of tall objects on wind speed near the ground.



Effect of topography on wind speed. *Left:* Speed increases as the wind flows over a smooth hill. *Right:* Speed may be higher in a valley (overhead view).

Types of rotors and wind machines

The rotors of wind machines are classified based on the orientation of the axis of rotation to the wind. A vertical-axis rotor accepts wind from any direction. As a result, quick changes in wind direction can be used efficiently. A horizontal-axis rotor is in line with the wind stream, so it is important to keep the rotor facing into the wind. A horizontal-axis rotor cannot use quick changes in wind direction as efficiently as a vertical-axis rotor machine.

Rotors can also be of the drag or lift variety. Drag rotors have lower efficiencies than lift rotors but develop higher torque, or turning power, at lower speeds. Lift rotors produce power from both drag and lift forces due to the airfoil shape of their blades. Therefore, lift rotors generally operate at higher efficiencies and develop more power per unit area.

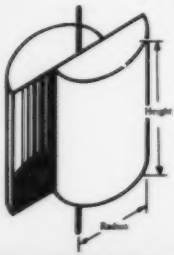
Vertical-axis wind turbine

Darrieus and Savonius rotors

The Darrieus rotor is a vertical-axis, lift type wind machine. It is often called an "egg beater" because its rotor resembles one.

The rotor has two or three blades with an airfoil cross-section. Its maximum efficiency is 42 per cent. Because of its low starting torque it is not self-starting. The Darrieus rotor turns at a speed suitable for powering a generator.

A Darrieus rotor can be started as a motor when interconnected with an electric utility. Sometimes a Savonius rotor is added to make a Darrieus self-starting.

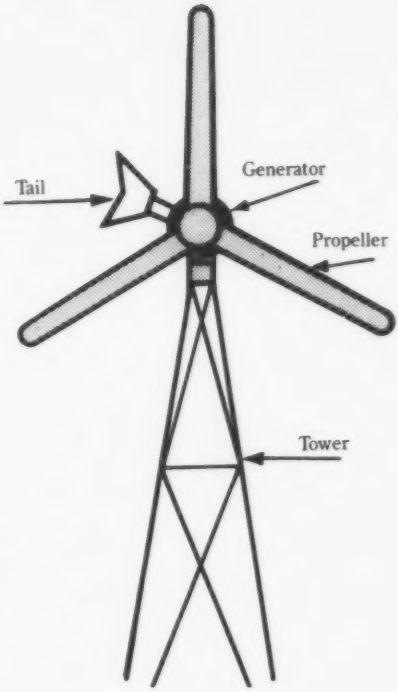


The Savonius rotor is a vertical-axis, drag type wind machine. The slow-turning rotor has a high starting torque and is well suited for pumping water.

Horizontal-axis wind turbine

High-speed propeller

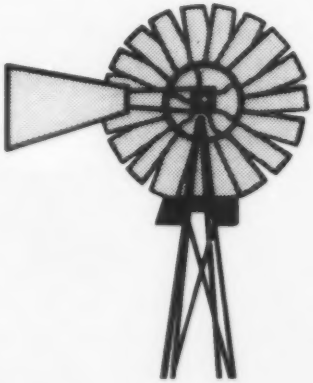
The high-speed propeller is of the lift type and has two or three airfoil blades. A three blade propeller is easier to balance. A horizontal-axis wind machine has a maximum efficiency of 42 per cent and a low starting torque. It is well suited to generating electricity.



Multiblade turbine

The rotor of a multiblade turbine has 15 to 40 blades on a horizontal axis. Since this rotor operates at a relatively low speed, rotor balance is not critical. Because of its high starting torque, the multiblade turbine is well suited for pumping water.

The rotor of most high-speed propellers and multiblade turbines face into the wind. Rudders or tail vanes are most commonly used, but some turbines use other mechanical means to face the propeller into the wind. Other types of high-speed propellers operate downwind, and may not require tail vanes.



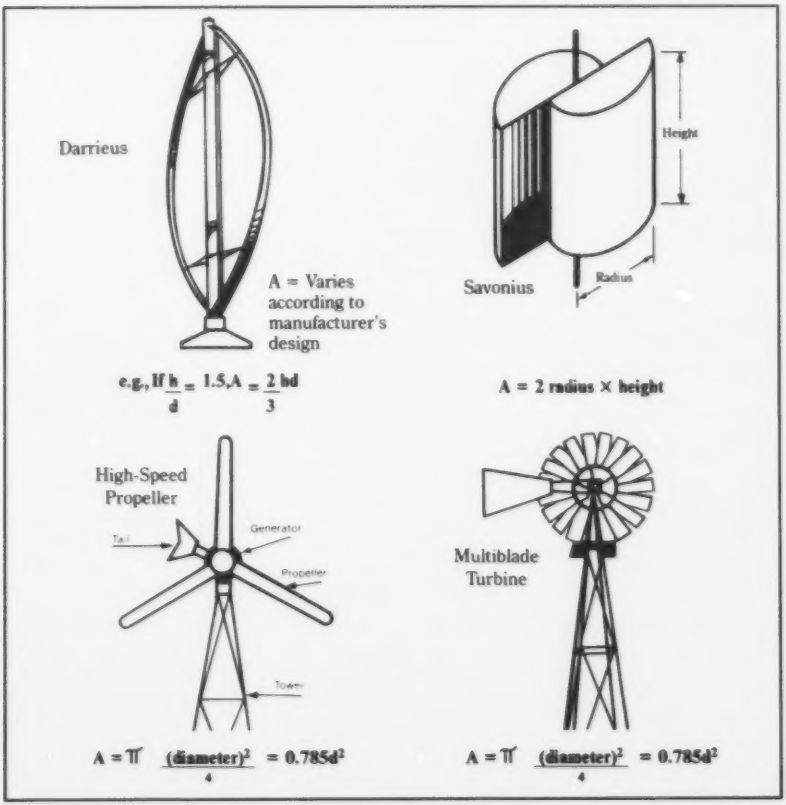
Calculating available wind energy

Maximum wind power is determined by measuring the area swept by the rotor and the cube of the wind speed:

$$\text{Power}_T = 0.0139 \times \text{area} \times (\text{wind speed})^3$$

Power_T	=	theoretical wind power in watts
0.01319	=	constant (assumes standard air density)
Area	=	area swept by the rotor in square metres
Wind Speed	=	speed in kilometres per hour

The following formulas are used to calculate useful area (A):



Unfortunately, it is not possible to harness all of the power in the wind. Power efficiency depends on wind machine design. The approximate peak efficiencies of the four different designs are listed at right.

Type	Per Cent
High-speed propeller	42
Darrieus	42
Multiblade turbine	30
Savonius rotor	16

These peak efficiencies usually occur at wind speeds of 30 kilometres per hour or faster. Efficiencies are lower in lighter winds.

A further reduction in efficiency occurs when shaft power is converted to electrical power. The reduction is caused by losses in gear boxes or pulley devices, in the alternator or generator, and in other power conversion equipment. The conversion efficiency can vary from 65 per cent to 80 per cent. For the purpose of estimating power, assume about a 75 per cent conversion efficiency.

Realistic total system efficiencies for the conversion of theoretical wind energy into electrical power are between 10 per cent and 30 per cent.

Recoverable power in watts =
$0.01319 \times \text{area} \times (\text{wind speed})^3 \times \text{system efficiency}$

System efficiency =
efficiency of rotor x conversion efficiency

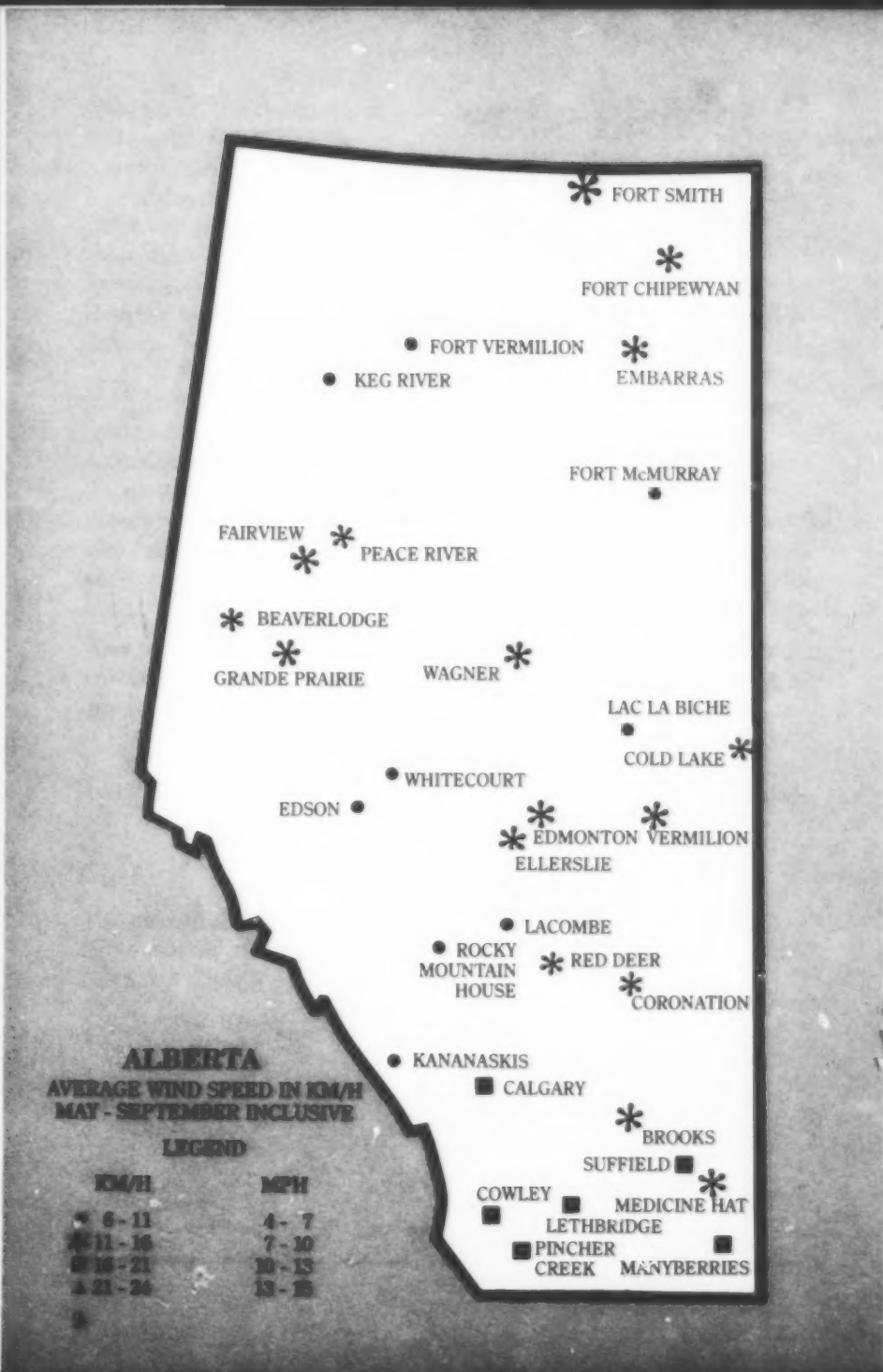
The potential power of a high-speed propeller wind machine, three metres in diameter when wind speed is 35 kilometres per hour, is calculated as follows:

Area	=	**$0.785 \times (\text{diameter})^2 = 0.785 \times (3)^2$**
	=	**$7.07\ m^2$**
Wind speed	=	**35 km/h**
System efficiency	=	**$0.42 \times 0.75 = 0.32$**
Power	=	**$0.01319 \times 7.07 \times (35)^3 \times 0.32$**
	=	**1.3 kW**

Possible sites for wind power installations

The amount of power generated by a wind machine would vary considerably in different Alberta locations. Although wind speeds vary widely, some general trends do occur. For example, it is common to have higher wind speeds in the winter. Average annual wind speeds vary greatly from one location to another due to topography and local climate. In Alberta, wind speed and duration of usable wind generally increase from north to south. However, tree cover, and other geographical characteristics can lead to wind power differences of two to one in areas less than two kilometres apart.

As a result, wind energy differs greatly from site to site. Information from weather stations and area surveys should only be used as a general guideline when planning a wind machine site. Wind measurements should be made to determine the best site for a wind machine. Many types of wind measuring devices are available. The Atmospheric Environment Service can provide advice on wind patterns in a particular area.

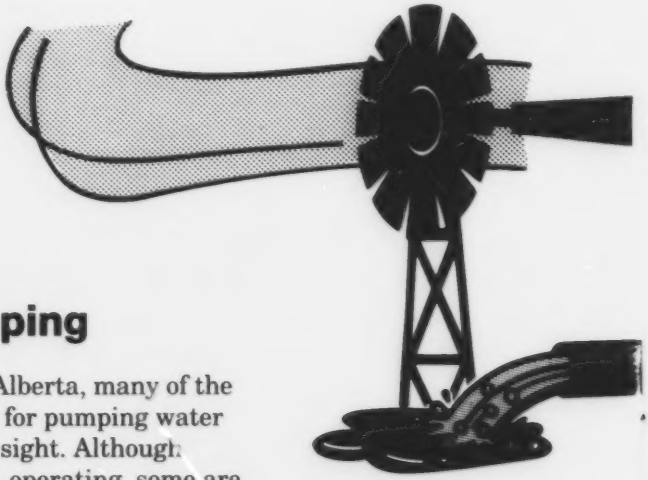

FORT SMITH
FORT CHIPEWYAN
FORT VERMILION
KEG RIVER
EMBARRAS
FORT McMURRAY
FAIRVIEW
PEACE RIVER
BEAVERLODGE
GRANDE PRAIRIE
WAGNER
LAC LA BICHE
COLD LAKE
WHITECOURT
EDSON
EDMONTON
VERMILION
ELLERSLIE
LACOMBE
ROCKY MOUNTAIN HOUSE
RED DEER
CORONATION
KANANASKIS
CALGARY
BROOKS
SUFFIELD
COWLEY
MEDICINE HAT
LETHBRIDGE
PINCHER CREEK
MANYBERRIES
ALBERTA
AVERAGE WIND SPEED IN KM/H
MAY - SEPTEMBER INCLUSIVE
LEGEND
KM/H
MPH
6 - 11
4 - 7
11 - 16
7 - 10
16 - 21
10 - 13
21 - 26
13 - 16

FORT SMITH
FORT CHIPEWYAN
FORT VERMILION
KEG RIVER
EMBARRAS
FORT McMURRAY
FAIRVIEW
PEACE RIVER
BEAVERLODGE
GRANDE PRAIRIE
WAGNER
LAC LA BICHE
COLD LAKE
WHITECOURT
EDSON
EDMONTON
VERMILION
ELLERSLIE
LACOMBE
ROCKY MOUNTAIN HOUSE
RED DEER
CORONATION
KANANASKIS
CALGARY
BROOKS
SUFFIELD
COWLEY
MEDICINE HAT
LETHBRIDGE
PINCHER CREEK
MANYBERRIES
ALBERTA
AVERAGE WIND SPEED IN KM/H
OCTOBER - APRIL INCLUSIVE
LEGEND
KM/H
MPH
6 - 11
4 - 7
11 - 16
7 - 10
16 - 21
10 - 13
21 - 26
13 - 15

Possible uses of wind machines

Wide variations in wind energy may occur over short time periods. These variations make short-term storage or a backup energy system an important part of most wind machine applications.

However, the need for storage or a backup system depends on how the wind-generated energy is used. Water pumping, for example, can usually operate with intermittent power. Similar uses may be auxiliary heating for homes or water.



Water pumping

Throughout rural Alberta, many of the old windmills used for pumping water are still a common sight. Although most are no longer operating, some are still used to pump water for livestock.

Attempts are now under way in Alberta and other parts of the world to devise wind-powered pumping systems for drainage, irrigation systems or watering livestock.

Most pumps on the market today are for horizontal-axis wind machines.

They usually consist of a rotor, crankshaft and mechanical assembly driving a conventional piston pump. Most piston pumps have adjustable strokes. A short stroke increases the height to which water can be pumped but it also reduces the volume pumped. A long stroke, on the other hand, increases pumping capacity but reduces the elevation.

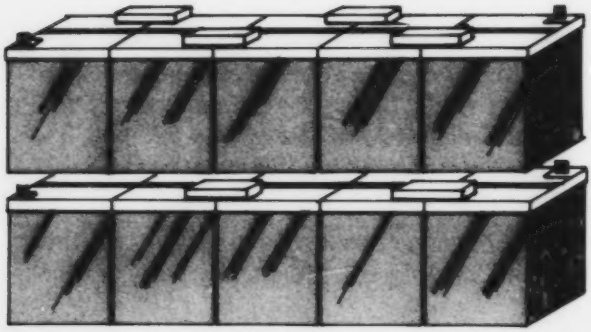
The wind machine and pump must be matched both to each other and the pumping application, to ensure satisfactory performance.

Electricity

A major drawback of wind-generated electricity is the inconsistent production of usable energy. Frequent changes in wind speed can cause problems, since output voltage and frequency of the generator may change with speed. And that is a problem because most electrical equipment requires alternating current (AC) with a constant 120 volts at a frequency of 60 Hertz. Some larger equipment requires 240 volts. However, there are some solutions to this problem.

One solution is to interconnect an alternating current induction generator with an electrical utility, to match the frequency and voltage of the utility supply. An induction generator requires appropriate controls to ensure proper and safe operation. Most manufacturers include these controls with their electricity-generating wind machines.

Another solution is to use a direct current (DC) generator and store electrical energy by charging batteries. However, battery storage systems are expensive, require regular maintenance, and usually result in some loss of energy.



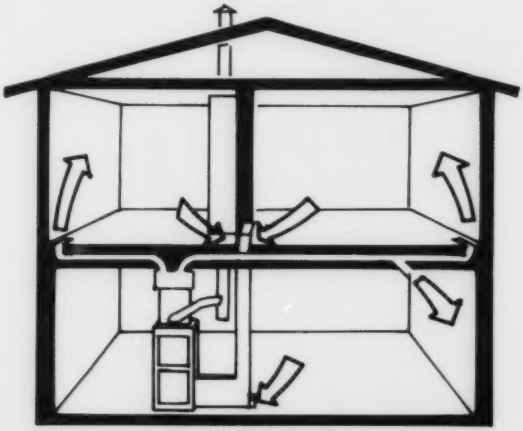
Battery banks

Only deep-discharge or deep-cycle batteries can withstand the extremes of charging and discharging over long periods. Ordinary car or truck batteries are subject to plate decomposition or buckling under deep discharge. Batteries should be stored in a warm area for maximum efficiency. A half-charged battery will freeze at –21°C, while a completely discharged one will freeze at –8°C.

DC energy from the generator or batteries may be used directly by DC lights, special DC appliances, and other DC equipment, or an inverter may be used to produce AC electricity.

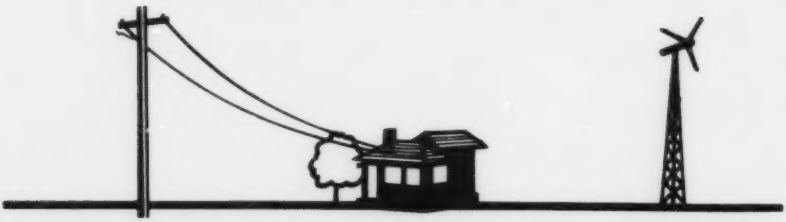
If storage is not required, the inverter may be connected directly to the generator, eliminating the high cost and maintenance of batteries.

A third solution is to use wind-generated electricity to perform tasks that do not require constant voltage or frequency. One such task is electric home or barn heating, when a backup system is available. Another use is electric water heating.



Electric heating

Interconnection of Small Wind Energy Conversion Systems



A Small Wind Energy Conversion System (SWECS) is a wind machine that is interconnected to an electrical distribution system so that it can both supply power to and draw power from the electrical grid.

There are three reasons why SWECS owners request interconnection with the utility. First, some SWECS have induction generators and require a utility supply for starting and operating. Second, most wind machines have inconsistent production, and so SWECS owners require utility backup to supply their needs when there is no wind. Third, there may be times when SWECS have excess electricity to supply to the utility.

Many of the SWECS in Alberta are interconnected with TransAlta Utilities. This interconnection has presented TransAlta with some unique situations. The areas of protection, safety, rates, metering and insurance are some of the concerns shared by TransAlta and the owners of the SWECS.

For a more detailed description of TransAlta Utilities' interconnection requirements, contact:

Power Planning, TransAlta Utilities, Box 1900, Calgary, Alberta, T2P 2M1

Telephone: (403) 267-3730.

The technical requirements and energy pricing policies governing SWECS are found in the following sections.

Interconnection policy of TransAlta Utilities

TransAlta Utilities will permit any customer to operate wind generating equipment in parallel with its electric system providing certain requirements are met. The following requirements are general in nature, and TransAlta reviews each facility on its own merits prior to interconnection. All costs associated with these requirements are the responsibility of the customer.

The utility and the owner of the generator must agree to a contract covering the interconnection, including requirements for insurance. As well, the owner will require approval from the Alberta Energy Resources Conservation Board (ERCB) and any other provincial or municipal agencies involved.

Technical considerations

1. A switch between the generator and the service panel must be able to be locked open to provide a visible disconnect device.
2. Synchronous and other generators with stand-alone capability must have a means of synchronizing to TransAlta's system.
3. Overvoltage and undervoltage protection must be provided.
4. Overfrequency and underfrequency protection must be provided.
5. The generator must automatically disconnect from the electric system in the event of a power outage on the electric system.
6. Generator overload protection must be provided.
7. The harmonic content of the generator output must be within acceptable limits, and voltage and current wave-forms must be satisfactory.
8. Separate measurement of power flow from the generator and to the customer load is required. This usually requires two meters.
9. All equipment must be approved by the Canadian Standards Association (CSA) and installed in accordance with the Canadian Electrical Code. If equipment has not yet received CSA approval, it must be approved by the Electrical Protection Branch of Alberta Labour.

Energy pricing

Self generation

Any customer can install a wind machine to decrease the amount of energy purchased from the electric system. TransAlta Utilities would negotiate a contract to purchase any excess energy that may be generated from time to time. The price paid for this excess energy would reflect the lower value of energy which is only available from time to time, and would likely be in the order of one cent per kilowatt-hour.

Competitive procurement

In 1992, TransAlta announced its intention to introduce a competitive procurement process for the supply of electricity from independent power producers. Through this competitive procurement process, TransAlta will request independent power producers to submit proposals to compete for the provision of future incremental electricity requirements. For further details, contact TransAlta.

Other programs

In 1988, the Government of Alberta legislated the Small Power Research and Development Program (SPR&D). The program was established to encourage small power producers using renewable wind, solar, hydro and biomass resources. Under the program, the small power producer signed a 10 to 20 year contract with the utility to sell all electricity produced by the generator at a price that was 5.2 cents/kWh in 1992, and increased in subsequent years. On June 25, 1992, the government confirmed that the program was fully allocated and that applications for new SPR&D projects were no longer being accepted.

In 1984, the ERCB introduced Net Energy Banking for a five-year trial period. Net Energy Banking was established specifically for small wind machines of less than 100 kW. The trial period ended on December 31, 1989, and Net Energy Banking is no longer available.

Costs

Costs of SWECS vary depending on type, size and manufacturer. There are several suppliers in Alberta and other parts of Canada offering new and rebuilt machines at various costs.

Capital cost is the major expense in using wind energy; therefore, the cost per kilowatt-hour can be reduced if capital costs can be reduced. The availability of utility service can also significantly influence cost. If utility service is available, it can serve as a backup supply, and eliminate the need for a costly storage system. However, as previously mentioned, some interconnection costs will be incurred to ensure safety and protection.

When utility service is not available, such as in remote locations, consideration must be given to the most reliable form of electrical supply. The most common method of backup and storage is battery banks or propane or diesel generators, or a combination of the two, depending on the type of load.

Other factors affecting the cost per kilowatt-hour and the payback period are: system life, average wind speed, maintenance requirements, site selection and purchased power rate.

For residential or small farm installations, wind machines in the two kW to five kW range may be sufficient. The installed cost of a system such as this would be approximately $4,000 per kilowatt.

When considering a wind machine to generate electricity answer the following questions:

- Is there enough wind?
- How much energy do I need?
- What are my alternatives?
- What are the costs?

More information

A good place to start any information search is a local library. Libraries usually contain considerable literature on wind power and other sources of renewable energy. On-line literature searches on a wide range of databases covering renewable energy information may also be available. In addition most libraries lend books and reports though the interlibrary loan service.

A good source of information on water pumping wind machines is the Alberta Renewable Energy Test Site (ARETS). Previously called the Lethbridge Wind Research Test Site, it was established in 1982. Its original objectives were to evaluate and demonstrate water pumping wind machines for local agricultural applications. The test site has since diversified to include solar pumping systems.

In 1991, the facility was moved to a location on Highway 3 east of the Town of Pincher Creek. The ARETS has the capability of testing, demonstrating and providing research and development assistance on wind machines and solar power systems.

If you plan to install a wind machine and interconnect with an electric utility, you must first obtain approval for its installation and operation from the Alberta Energy Resources Conservation Board. The Board's requirements for approval of small power plants are outlined in the Regulation of Small Power Plants and Pilot Projects brochure and Small Power Plant and Pilot Project Applications — A Guide to Content (Guide G-39).

Information on the performance of wind machines that have been tested may be obtained from:

The Alberta Renewable
Energy Test Site
Alberta Farm Machinery
Research Centre
3000 College Drive
Lethbridge, Alberta T1K 1L6
Telephone: (403) 329-1212

Requests for copies of the Energy Resources Conservation Board publications should be made to:

Energy Resources
Conservation Board
Hydro and Electric Department
640 - 5th Avenue SW
Calgary, Alberta T2P 3G4
Telephone: (403) 297-8344

Alberta
AGRICULTURE

TransAlta Utilities

Ptd. 07-83-14M
Rev. 10-84-4M
Rev. 04-86-4M
Rev. 02-87-3M
Rev. 04-89-2M
Rev. 08-92-4M

339-1018

Printed on Recycled Paper